Chapter 1: Introduction to SIPs

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Introduction

Builders everywhere are learning the benefits of building with structural insulated panels (SIPs). SIPs are a panelized building system composed of rigid foam insulation sandwiched between two structural facings, such as oriented strand board (OSB). Although SIPs can be made with a number of different materials, the basic concept remains the same: by distributing the structural loads present in a building over the structural facings, SIPs greatly reduce the number of structural members needed. Less lumber or steel translates to less thermal bridging and better airtightness for a more energy-efficient structure.

This chapter traces the development of SIPs from the 1930's to today's automated fabrication facilities. It also gives an overview of common SIP applications and the different types of materials used to construct SIPs.

Definitions

Structural insulated panel (SIP)	Panelized building system composed of rigid foam insulation sandwiched between two structural facings, such as oriented strand board
Oriented strand board (OSB)	Structural wood panel comprised of wood strands arranged in cross-oriented layers, similar to plywood
R-value	Measure of thermal resistance of a building material, such as insulation
Permeability	Measure of the amount of water vapor that can pass through a specified material in a certain amount of time
Green building	Process of designing and constructing buildings that have a lower impact on the environment

History of SIPs

The history of SIPs originates with a series of test homes constructed at the Forest Products Laboratory in Madison, Wisconsin during the 1930's. Researchers were looking at ways to use wood products more efficiently by designing a panelized wall system where the plywood sheathing carried a portion of the axial load.

Famed architect Frank Lloyd Wright used this concept in his affordable Usonian houses built throughout the 1930's and 1940's. Many of these homes, along with the test homes constructed by the Forest Products Laboratory, are still standing today.

The creation of the modern structural insulated panel is largely credited to Alden B. Dow, one of Wright's students and son of the founder of The Dow Chemical Company. Dow expanded on the ideas and technologies developed by the Forest Products Laboratory to produce the first laminated SIP with a core of insulating foam.

Continued improvements to SIP technology led to a small but vibrant industry that received a major boost from a resurging interest in timber framing in the 1960's and 1970's. Timber frame builders quickly found SIPs an incredibly time-efficient method to enclose timber frame structures. The marriage of cutting edge technology and traditional building techniques provided an effective solution for timber frame builders and propelled SIPs into the residential construction market.

Modern Technology

The SIP industry's next evolutionary milestone came from two major advancements in SIP production. In the 1990's, SIP manufacturers adopted computer numeric control (CNC) fabrication machinery. With the introduction of CNC equipment and other computer technology, manufacturers gained the ability to transfer computer aided design (CAD) files directly into fabrication equipment and cut panels with precise tolerances. CNC automation greatly increased production efficiency and consequently reduced the price of prefabricated SIPs.

At the same time, the oriented strand board (OSB) industry introduced "jumbo" 8-foot by 24-foot structural panels. SIP manufacturers were quick to adopt the larger panels and produce SIPs of the same size, allowing SIP buildings to be constructed faster and with fewer joints. SIP manufacturers again benefited from greater production efficiency and the expanded breadth of building applications now capable with SIP construction.

Green Building

The latest influential event in the growth of the SIP industry is the rise of green building. Since the advent of the first foam core SIP in the early 1950's, SIPs have been an inherently energy-efficient product. The building industry's recent interest in energy efficiency and environmentally sustainable construction has generated unprecedented interest in building with SIPs.

The last twenty years have witnessed the emergence of a handful of voluntary energy efficiency and green building programs, such as ENERGY STAR®, EarthCraft, Green Globes, and the popular LEED body of rating systems. State and local energy codes have increased, and a number of federal, state and local tax incentives are pushing the market toward energy-saving building technologies. Designers and builders using SIPs have an easy time meeting the requirements of these various green building programs and tax incentives with a SIP building envelope.

The Structural Insulated Panel Association (SIPA)

SIPA was formed in 1990 by a group of SIP manufacturers with the goal of increasing the use and acceptance of SIPs through education, collective marketing and technical research. The association now includes suppliers of SIP components, dealer/distributors, builders and design professionals—all devoted to making SIPs the preferred green building system.

SIPA participates in a number of activities to this end, including:

- National marketing campaigns
- Technical research
- Builder and architect education
- Consumer outreach
- Code advocacy

SIP Applications

Walls

SIPs work very well in wall applications. Chapter 2 will cover the structural characteristics of SIPs in more detail, but SIPs are very strong under the axial and racking load conditions present in wall applications, far surpassing standard wood frame construction. SIP walls are available in a variety of thicknesses with different R-values and performance characteristics. SIP walls go up quickly, are extremely straight, and help create an airtight building envelope.

Roofs

In roof applications, SIPs reduce framing time, improve energy efficiency, and create a vaulted or cathedral ceiling. Using a SIP roof also creates a conditioned attic, which has many energy efficiency benefits that will be discussed in greater detail in Chapter 4.

SIP roofs have received criticism in the past, with claims that the product lost its installation efficiency on complicated roof designs. However, today's advanced design software and automated fabrication enable skilled SIP designers and installers to create complex roof lines in a fraction of the time.

Floors

Although it is fairly uncommon, SIPs can be used in floor applications. SIP floors account for only 3 to 4 percent of SIPs produced in North America. SIP floors are typically used over unconditioned space, such as homes built on pilings in unstable soil conditions. In these situations, SIP floors provide excellent insulation and do not squeak.

One of the disadvantages of using SIP floors is the increased risk of water damage to OSB skins during the construction process. Unlike walls or roofs, floors have the ability to pool water and will be exposed for longer periods of time before the building can be dried in. OSB-faced SIPs need to be given adequate time to dry if they are exposed to moisture, or moisture can be trapped under subflooring and floor coverings. OSB facings also have limited point load resistance. For this reason they typically require the application of subflooring on top of the OSB facings to prevent puncture.

Types of SIPs

A structural insulated panel is composed of three components: the outside facing, the inner core, and the adhesive that binds the two together. There are a variety of different facing and core materials offered by SIP manufacturers. Selecting the appropriate type of SIP may depend on individual project conditions, cost and availability.

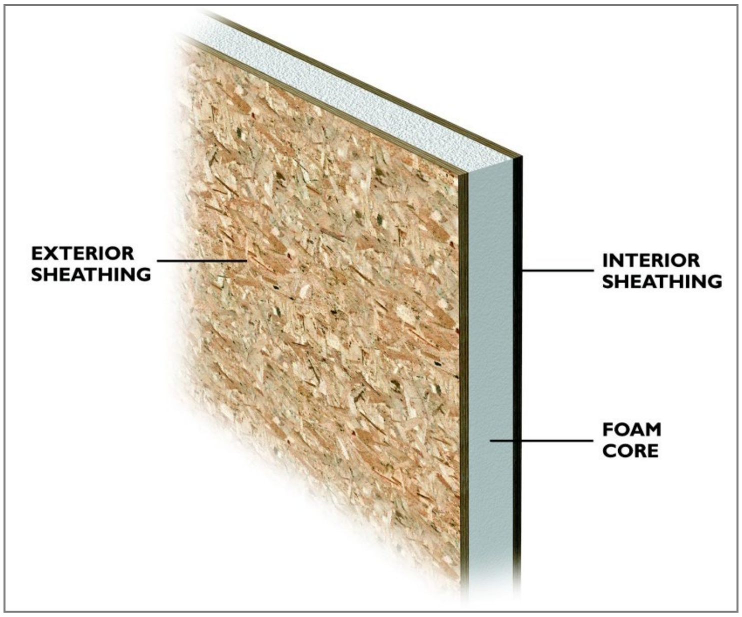

Figure 1: Anatomy of a SIP

SIP Facings

There are a variety of different facing materials offered by SIP manufacturers. The three most commonly used facing materials are OSB, metal, and cementitious or fiber cement panels.

The most popular facing used is OSB, although metal and cementitious facings are often used in situations where working with wood is a disadvantage. In some cases, a finished cladding material, such as drywall or wood paneling, may be used as a SIP facing.

- **Oriented Strand Board (OSB)** – Wood structural panel composed of layered, cross-oriented wood strands and bonded with a moisture-resistant adhesive
- **Metal –** Light gauge metal facings typically come from rolled stock and function as a finish material
- **Cementitious** – Also referred to as fiber cement, cementitious facings are a composite material made of cement, sand and cellulose fibers
- **Finish Materials** – Gypsum wall board or wood paneling is sometimes used as the interior facing in specialty applications where field application would prove difficult

Properties of SIP Facing Materials

Size

OSB facings are the only panel available in the 8-foot by 24-foot jumbo format. Large panels translate to fewer joints and quicker assembly.

Metal panels are made from rolled stock, allowing metal SIPs to be manufactured to almost any easily transportable length, but with a limited width of 4 feet. Cementitious panels are commonly available in 4 by 8-foot sections, and in some cases 4 by 12-foot or 4 by 14-foot sizes.

Ease of Assembly

The ease of assembly will largely depend on the installer's familiarity with wood, metal or cementitious construction. For installers accustomed to wood frame construction, dealing with OSB-faced panels will be the easiest. OSB-faced SIPs are typically assembled using pneumatic nail guns and are relatively easy to handle. Metal and cementitious SIPs are assembled using screws instead of nails.

In the event that SIPs need to modified onsite, OSB skins are easily cut using standard carpentry tools. Metal panels can also be modified with little difficulty, but cementitious panels require specialty tools and onsite dust control for worker safety.

The type of panel facing can also greatly affect the weight of the panels and how materials are handled on the jobsite. OSB-faced SIPs weigh an average of 4 pounds per square foot, meaning a 4 by 8-foot OSB-faced SIP weighs close to 130 pounds and can be moved onsite without handling equipment.

Whereas metal-faced panels are much lighter than OSB-faced panels, cementitious SIPs panels weigh more than twice as much. A 4-foot by 8-foot cementitious SIP weighs over 250 pounds. It is difficult to move around the jobsite and can slow down the installation process.

Moisture

In the construction environment, exposure to moisture is often unavoidable. The OSB used on SIPs is rated Exterior – Exposure 1, meaning it has the ability to withstand temporary exposure to moisture if it is given the opportunity to dry. This needs to be taken into account when detailing and finishing SIP buildings with OSB skins. Proper detailing will be addressed in detail in Chapter 9.

Metal facings are not significantly affected by exposure to moisture. Cementitious skins offer increased moisture resistance, but will expand with the absorption of moisture and contract when drying.

Finish Materials

Metal and cementitious skins have the ability to be used as a finish material. One thing to consider when using panel skins as finish materials is that a major structural element of the building will be exposed to the elements over the life of the structure. Interior finish materials like gypsum wall board or wood panel are exposed to weather on the jobsite and are easily damaged during installation.

Insect resistance

Termites and carpenter ants consume wood and other cellulosic materials. SIPs with metal or cementitious skins do not contain wood and therefore are more termite resistant. For this reason, metal and cementitious SIPs are popular in the Southern U.S. and Central America.

SIP Core Materials

There are three different types of insulating foam used in SIPs: expanded polystyrene (EPS), extruded polystyrene (XPS) and polyurethane. All types of cores offer relatively comparable insulation value and performance characteristics.

Properties of SIP Core Materials

R-value

R-value is a measure of a material's resistance to thermal conductivity. A higher R-value indicates a greater resistance to thermal conductivity and better performance as an insulating material. Traditionally, much emphasis has been placed on R-value in improving the energy efficiency of the building envelope, but more recent studies indicate that air leakage is responsible for as much as 40 percent of a home's heat loss.

Each SIP manufacturer has published R-values that are based on standardized testing methods. EPS foam has the lowest R-value per inch, followed by XPS. Polyurethane foam has the highest R-value per inch of material thickness. This does not mean high R-values cannot be achieved with EPS or XPS SIPs, only that it may require a thicker SIP to achieve the same R-value.

Rigid polyurethane foam undergoes a process known as thermal drift, where the gaseous blowing agent used in the manufacturing process slowly bleeds out of the finished product and reduces its R-value to a certain point. For this reason, SIP manufacturers will reference the steady state R-value or aged R-value that takes this degradation into effect.

Permeability

Permeability is a measure of the amount of water vapor that can pass through a specified material in a certain amount of time. It is measured in perms. A high perm value means moisture transfers through a material or assembly at a fast rate.[1]

Although perm ratings for SIPs will vary by the thickness and type of core material used, all foam-core SIPs have a relatively low perm rating. A 4-inch SIP with OSB facings and an EPS core meets the building code requirements for a vapor retarder (US-IBC-1.0 perms). No additional interior plastic polyethylene vapor barrier is required or desirable, with the exception of subarctic and arctic climates.

[1] The following material is paraphrased from *Builder's Guide to Structural Insulated Panels (SIPs)* by Joseph Lstiburek. Building Science Press, 2008.

The perm ratings for XPS and polyurethane are lower than EPS, and therefore SIPs with these core materials would have lower perm ratings.

SIPs are typically bilaterally symmetrical in terms of permeability. The resistance to vapor flow is identical from one side of the panel centerline to the next. Wall and roof assemblies are often designed with vapor flow inward or outward, depending on climatic conditions. With SIPs, the resistance to vapor flow inward and outward is the same, allowing the product to be used in virtually any climate zone.[2]

Fire Resistance

There is a lot of misinformation about the fire resistance of SIPs. Fire ratings and fire resistance are a function of the entire wall or roof assembly, not the individual components, such as the SIP cores or facings.

Residential SIP structures typically require the application of a 15-minute fire-resistant thermal barrier on the interior, such as ½-inch-thick gypsum board or a material of equivalent thermal performance. Light commercial or multi-use buildings of Type V Fire Rated construction may require a one-hour fire rating and/or sprinkler systems. When a one-hour fire rated assembly is required, SIP manufacturers can provide tested assemblies for both walls and roofs that meet the one-hour fire resistance tests outlined in ASTM E 119.[3]

As with any fire resistance issue, the local jurisdiction requirements will vary by region. Contact your local building department to determine the requirements in your area.

Core Thickness

The different core materials used in SIPs have vastly different manufacturing processes that determine their maximum available thickness. SIPs with EPS and XPS cores are typically available in sizes ranging from a 3 ½-inch core (4 ½-inch total panel thickness) to a 14-inch core (15-inch total panel thickness). SIPs are often described using nominal sizing, where a nominal 4-inch SIP (4 ½-inch actual total panel thickness) will be used with nominal 2 x 4 dimensional lumber (3 ½-inch actual width) that matches the thickness of the SIP core and fits in panel recesses for end plates, blocking, splines, or other uses.

Polyurethane core panels are commonly available in 3 ½-inch core (4 ½-inch total panel thickness), 5 ½-inch core (6 ½-inch total panel thickness), and 8 ¼-inch core (9 ¼-inch total panel thickness).

Insect Resistance

To prevent the intrusion of termites or carpenter ants, many SIP manufacturers offer EPS cores infused with borates. This treatment is only available on SIPs with EPS cores. Borate-treated EPS

[2] In subarctic/arctic climates it may be necessary to install a fully adhered impermeable membrane
[3] See SIPA Technical Bulletin No. 2, Fire Safety with Structural Insulated Panel Construction

is not a substitute for proper termite prevention in high-termite areas. Careful termite prevention should be followed, as with any other wood structure.

Summary

Starting in the 1930's, researchers began experimenting with ways that structural sheathing could carry part of the axial loads present in residential structures. That concept has been refined into modern structural insulated panels (SIPs) – a structurally self-sufficient building system that delivers unparalleled energy efficiency and speed of construction. As the SIP industry progressed, the Structural Insulated Panel Association (SIPA) was formed to address industry-wide needs for education, marketing and technical research.

SIPs are available in a number of different material combinations. Selecting the right materials depends on local availability, climate conditions, cost and other factors.